THE INFLUENCE OF A WATERPROOFING AGENT ON SOIL MOISTURE PROPERTIES

by

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INTRODUCTION AND LITERATURE REVIEW

Recent drought conditions throughout the Great Plains have pointedly demonstrated the effect of insufficient soil moisture on crop yields. Of the factors contributing to such soil moisture deficiency, evaporation is one of the most important. Hide (10) estimated that 70 to 75 percent of the total precipitation received in the dryland areas has been lost through this medium. Duley and Russell (2) rate the evaporation losses in soil moisture as being equal to or exceeding that used by crops and two to four times that amount lost by runoff.

The importance of soil moisture loss by evaporation has been realized for many years. Transeau (19), as early as 1905, developed an index of precipitation effectiveness by using the quotient of total annual precipitation and annual evaporation. Thornthwaite (18) utilized a modified version of Transeau's original concept to classify the climates of North America.

The reduction of soil moisture loss has been the subject of many past and present experiments. The majority of such work has centered around the employment of various types of mulches. King (12), in 1907, reported a 63 percent reduction in evaporation of soil moisture by the use of dust mulches. However, Veihmeyer, et al. (21) has shown that before a dust mulch can be formed, most of the soil moisture must have already been lost.

In some areas stone mulches have been tried. Lamb and Chapman (14), in New York, were able to determine small reductions in evaporation by covering up to 65 percent of the surface area with stones. Tsiang (20) reported the partial control of evaporation in some of the dryland areas of China by the use of pebble mulches.

Of the numerous works involving mulches, probably the majority have been with plant residues. Esser (3), in 1884, used chopped straw, beech leaves,

pine needles, and fir needles for soil mulches. An application of chopped straw 5 centimeters deep to a 1000 square centimeter area reduced evaporation 90.5 percent; the other mulches proved almost as effective as the straw.

Duley and Russell (2), working in Nebraska with straw mulches, showed that of the 17.9 inches of rainfall received from April 23 to September 8, 1938, 54.3 percent was saved by a 2-ton per acre application. At the same time only 20.7 percent of the total precipitation was saved on a plowed bare plot. These savings resulted from reduction in both runoff and evaporation. In this experiment the results of basin listing were of interest because, while there was no runoff, the amount of water conserved was only half that amount stored under the straw mulch. This demonstrates that prevention of runoff alone is not the complete solution for moisture conservation in the Great Plains.

Russell (16), in a further analysis of the work by Duley and Russell (2), reported the percent of moisture lost only by evaporation. The various treatments and their respective losses were as follows: 2-ton per acre straw mulch, 46 percent; plowed black fallow, 68 percent; contour listing, 72 percent. Thus the use of straw resulted in a 22 to 26 percent savings in soil moisture.

However when these evaporation rates were determined over a shorter time period, there appeared a different pattern of results. From May 24 to August 9, the total precipitation was 5.6 inches with only three rain storms greater than 0.5 inches. Of the moisture received during this period, 99 percent was lost by evaporation from the 2-ton per acre straw mulch plot while 97 and 95 percent were lost, respectively, from the plowed black fallow and contour listing plots. Thus Russell concludes, "Residues on the surface may very decidedly reduce losses by evaporation during periods of frequently recurring rains, but may be of little value in this respect when rains are few and scattered."

Lemon (15), working with mulches in Texas, used two different types of plant residues with applications of 10 tons to the acre. Despite the fact that the plots were constructed to prevent runoff, there was no conservation of soil moisture due to mulching. It was noted that the soil temperatures beneath the mulches were not reduced as might be expected; in fact, at some depths the temperatures were increased.

Zingg and Whitfield (22), in a summary of stubble mulch research, have presented data from five different western areas which indicate that the conservation of soil moisture by mulching is slight. These research projects from which this data was collected had a duration ranging from 3 to 11 years.

While more work has been done on the reduction of evaporation by mulches, in general the results are somewhat contradictory and indecisive. This statement holds especially true for the Great Plains areas.

Recently the problem of reducing the evaporation of soil moisture has been approached by other means; that being the disruption of capillary continuity to the soil surface. Essentially such a reduction in capillary movement would allow evaporation to take place only through the medium of vapor diffusion. This elimination of one avenue of moisture loss will reduce the over-all evaporation rate.

Kolasew (13), a Russian, has reportedly decreased moisture loss under wind tunnel conditions by the employment of physical means to disrupt capillary continuity. These physical means consisted of stratifying the soil by the formation of alternate compacted and loose layers. The bulk densities of the compacted layers were 1.3 times those of the loose layers. Reduction in moisture loss was attributed to both the decrease in capillary continuity because of isolation of compacted layers and restriction of vapor diffusion through the compacted layer due to decreased porosity.

Currently there is being shown considerable interest in the reactions of organic compounds with soils. While most of such interest has been concerned with their use as soil conditioners, nevertheless there is evidence to indicate the possibility that certain organic compound might be used for evaporation reduction. Disruption of capillary continuity is probably the mechanism involved; disruption presumably resulting from changes in the wetting angle.

Grim, et al. (5), in working with illite, kaolinite, and montmorillonite clays, found that the addition of amines and other large organic molecules greatly reduced the ability of the clays to absorb water.

Hendricks (9) also demonstrated that montmorillonite treated with amine salts absorbed less water than sodium and calcium clays.

Hauser and Jordan (7), using fatty quaternary ammonium and other amine compounds, caused colloidal silica and clays to become hydrophobic.

Kolasew (13), after treating plots with a naptha soap compound, observed that the surface dried much faster than that of the untreated plots. The treatment resulted in the top three centimeters becoming hydrophobic and decreasing its ability to conduct capillary water. Sukhovolshaia (17) decreased evaporation six to seven times by the addition of 0.2 percent naptha soap to the top one centimeter of soil.

The use by Hedrich and Mowry (8) of a carboxylated polymer soil conditioner in low concentrations resulted in a considerable reduction in the rate of evaporation. When using a soil with an initial moisture content of 23 percent, the control lost one-half this amount by evaporation in a 15 day period compared to 35 days for the treated soil.

Felber (4), by mixing methylcellulose with potted composted soils, reported substantial savings in soil moisture. While the methylcellulose was applied both as a hydrophilic dispersion and as dry fibers, the dispersion

proved the most effective. When moisture losses were determined and replaced daily, savings as high as 70 percent were reported from bare soils. However, the application of methylcellulose to a light field soil was not too effective.

Recently the fatty quaternary ammonium compounds have been used in highway research. Hoover and Davidson (11) studied 19 of these organic cationic chemicals as stabilizing agents for loess. Of this group Arquad 2HT[1] proved particularly promising because of its favorable effect on such properties as immersed compressive strength, moisture absorption, and swelling. Equally important was its commercial availability, economy of cost, and ease of preparation and mixing with soils.

Arquad 2HT is commercially supplied 75 percent active in isoproponal and is easily dispersed in water up to 8 percent by weight. The molecules are large with an average molecular weight of 585. Its general structural formula is as follows:

$$\left[\begin{array}{c} CH_3 \\ | \\ R - N - CH_3 \\ | \\ R \end{array} \right]^{+} (CL)^{-}$$

Grossi and Woolsey (6), in determining the effects of Arquad 2HT on the physical properties of certain soils, have demonstrated the possibility of its utilization in evaporation control by the reduction of capillary movement. As seen in Table 1, an Arquad 2HT treated Putman silt loam soil column increased only 1.89 percent in weight over a 23 day period by the capillary movement of water. For this same period the untreated soil column showed a 40.09 percent

[1]Arquad 2HT is one of the commercial brand names for di-hydrogenated tallow dimethyl ammonium chloride. Throughout this paper the commercial name Arquad 2HT will be used.

weight increase. In both cases the soil was in direct contact with water saturated cotton.

Table 1*. Increase in weight (%) of column of soil by capillarity.

Test duration days	Weight Putman silt loam Grams			Weight Putman silt loam treated with 0.1% Arquad Grams		
	Dry soil	Wet soil	% gain	Dry soil	Wet soil	% gain
2	28.46	39.57	39.04	29.13	29.72	2.03
7	-----	39.85	40.02	-----	29.90	2.64
16	-----	39.46	38.65	-----	29.88	2.58
23	-----	29.87	40.09	-----	29.68	1.89

*From original article by Grossi and Woolsey.

Despite the quantity of work done on the problem of soil moisture conservation, no definite solution has been found. The need to reduce evaporation is just as pressing today as in the time of King (12), 50 years ago. The uncertainty of rainfall throughout the Great Plains and the economic dependence of this area upon successful crop yields demand that every possibility of conserving soil moisture be investigated.

Because of the promising aspects of Arquad 2HT in regard to disruption of capillary continuity, it is the purpose of this investigation to determine the feasibility of its utilization in the conservation of soil moisture.

EXPERIMENTAL PROCEDURES

Description and Preparation of Soils Used

Except where otherwise specified, the soils used in this experiment were as follows:

	Bulk density gms/cc	1/3 atmosphere %	15 atmosphere %
Ashland[1] fine sandy loam	1.5	13.8	5.0
Kaolinite subsoil	1.4	27.3	---
Wabash[1] silty clay loam	1.3	27.2	11.0
Ladysmith silty clay loam	1.2	29.0	16.5

Arquad 2HT, in preparation for soil treatment, was mixed to the various specified concentrations by placing a weighed amount into distilled water, stirring vigorously by hand, and diluting the resulting dispersion to the required volume.

The prepared Arquad 2HT dispersion was combined with the soil by allowing it to slowly drip onto a soil while stirring with an electric mixmaster. The amounts and concentrations added varied with the soils and the phase of the experiment. However, with one exception the amount added was sufficiently low so that the worked soils were not puddled.

After the desired volume of dispersion had been added, the treated soils were placed in an oven and dried at 50° C. for 24 hours. After drying, all soils were screened through a number 10 sieve.

Effect of Arquad 2HT on Evaporation from a Bare Soil

Arquad 2HT dispersion, in quantities sufficient to raise the moisture content of 3/4 of the 1/3 atmosphere percentage, was mixed with 500 gram samples from each of the four specified soils. The various applied dispersion concentrations were 0.1, 0.5, 1.0, and 2.0 percent. Because of differences in the 1/3 atmosphere percentages, soils treated with the same concentrations received different total amounts of Arquad 2HT. Table 2 shows the conversion

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[1] Tentative names.

of the amount of added Arquad 2HT dispersion of various concentrations to percent Arquad 2HT on a soil weight basis.

In preparation for the process of evaporation, the soils were placed in polyethylene tubes which were six inches high, two inches in diameter, and of known volume. The amount of soil added to each tube depended on the specified bulk densities.

In adding the soils, a cap was placed on the top of each tube, the tube was inverted, and the soil inserted into the tube through the bottom end. Where the experiment required a particular depth of Arquad 2HT treated soil, that soil was taken from a previously treated and predried sample and was placed in the tube first. After the treated soil had been placed in the tube, the remainder of the tube was filled with untreated soil.

Table 2. Conversion of added Arquad 2HT dispersion to percent of soil weight.

Soil type	Ml added to 500 grams	Concentration of Arquad 2HT 0.1%	0.5%	1.0%	2.0%
		% Arquad 2HT by soil weight			
Ashland fine sandy loam	47	0.007	0.035	0.07	0.14
Kaolinite subsoil	95	0.014	0.07	0.14	0.28
Wabash silty clay loam	80	0.012	0.06	0.12	0.24
Ladysmith silty clay loam	95	0.014	0.07	0.14	0.28

To achieve the required bulk densities, a piston-like plunger and a rubber mallet were used to compact the soils. The tubes were marked at 1/2 inch intervals and the soils were added and compacted in 12 increments of 1/2 inch each. In wetting the soils sufficient distilled water was added from a burette to bring the total mass of soil up to the 1/3 atmosphere percentage. As with the addition of the soils, the tubes were in the inverse position and the water was added at the bottom end.

After wetting, permanent caps were placed on the designated bottoms and the tubes were then reinverted to their normal positions. The tubes were wrapped in white paper for the purpose of insulation and then placed on a revolving turntable for a period of 14 days. Thus, the revolving tubes were exposed to the same environment. All treatments were made in duplicate.

This phase of the experiment, dealing with the effects of Arquad 2HT on evaporation, was divided into the following two sections.

Effect of Concentration of Arquad 2HT on Evaporation from a Bare Soil. The depth of treatment was kept constant at two inches. As previously described, the Arquad 2HT was added to the treated portions of each soil in dispersion concentrations of 0.1, 0.5, 1.0, and 2.0 percent; the over-all amounts applied varied as shown in Table 2. Control tubes were maintained on each soil. All tubes were weighed daily and the effectiveness of the various treatments was determined on the basis of grams of water lost.

Effect of Depth of Arquad 2HT Treatment on Evaporation from a Bare Soil. In this portion of the experiment the depth of treatment was varied at one, two, and three inches on each of the specified soils. Control tubes were maintained on each soil. Concentration of the applied Arquad 2HT dispersion was maintained constant at 1 percent; the total amount applied varied with the soil as is shown in Table 2. Again the tubes were weighed daily and the grams of water lost were used as a basis to judge the effectiveness of each treatment.

Effect of Arquad 2HT on Moisture Retention

The moisture equivalent percentage, as described by Briggs and McLane (1), was used to determine the influence of Arquad 2HT on the moisture retention of soils. The soils had been previously wet to 3/4 of the 1/3 atmosphere percentage with a 1 percent concentration of Arquad 2HT dispersion. They were then dried

at 50° C. before being used. The soils used were as follows: Summitt clay, Munjor silty clay loam, Garden City fine sandy loam, Albion fine sandy loam, Keith silt loam, and Ladysmith silty clay loam. The percent by weight of Arquad 2HT varied with the soils. All treatments were made in duplicate.

Effect of Arquad 2HT on the Exchange Capacity of Certain Clay Minerals

To determine the effect of Arquad 2HT on exchange capacity, duplicate 1/2 gram samples of Wyoming bentonite, Fithian illite, and Drybranch Georgia kaolinite clays were subjected to the following procedure:

(1) Wash clays four times with an excess of 1 N $CaCl_2$ to satisfy all charges with Ca^{++}.

(2) Wash clays four times with ethanol to remove excess Ca^{++}.

(3) Wash clays four times with an excess of 1 percent Arquad 2HT dispersion to replace Ca^{++}.

(4) Wash clays four times with an excess of 1 N NH_4Ac to replace Ca^{++} remaining on the clays.

(5) Save NH_4Ac supernatant liquid, dilute to 250 ml., and analyze on spectrophotometer for Ca^{++} displaced.

When the above procedure called for the washing of clays, this was done by mechanical dispersion in approximately 50 ml. of the specified reagents. The clays were then flocculated by centrifugation and the supernatant liquid was decanted.

The procedure for the determination of exchange capacity on the untreated clays was the same as that listed above except step 3; the washing of the clays with Arquad 2HT was eliminated. The extent of reaction between Arquad 2HT and the clays was equal to the difference in milliequivalents of Ca^{++}/100 grams

replaced from the treated clays and the exchange capacity in milliequivalents of Ca^{++}/100 grams for the untreated clays.

Determination of the Mechanism of Reaction Between Arquad 2HT and Certain Clay Minerals by the Use of X-ray Diffraction

In order to learn something of the mechanism by which Arquad 2HT reacts with soils, treated and untreated samples of calcium saturated Wyoming bentonite, Fithian illite, and Drybranch Georgia kaolinite were subjected to X-ray diffraction.

To prepare the clays, samples of each were washed four times with an excess of 1 percent Arquad 2HT dispersion and dried at 50° C. By X-ray diffraction "d" spacings of both treated and untreated clays were then determined and compared.

Next, samples of both treated and untreated Wyoming bentonite were placed in an oven for 24 hours at 130° C., the purpose being to remove the water and collapse the clay plates. These same samples were later expanded by placing them for 4 days in a dessiccator with a 100 percent relative humidity. At both the collapsed and expanded stages "d" spacings were measured.

Effect of Arquad 2HT on the Germination of Wheat Seed

If Arquad 2HT is to be utilized in agriculture it is of importance to determine its effect on plants. For the present this phase of the experiment has been limited to the determination of the influence of Arquad 2HT on the germination of wheat seed.

Duplicate 1000 gram samples of each of the four originally specified soils were wet to the 1/3 atmosphere moisture percentage with 0.1, 0.5, 1.0, and 2.0 percent concentrations of Arquad 2HT dispersions. The percent of added Arquad

2HT on a soil weight basis varied with each soil. The soils were placed in small pans and planted to a 1/2-inch depth with 100 certified Pawnee wheat seeds. The wheat seeds had a rated germination of 95 percent. All planted pans were then placed in a 100 percent relative humidity chamber for a period of 7 days. Effect of Arquad 2HT was determined on the basis of the number of seeds germinated.

Effect of Arquad 2HT on the Infiltration Rate into Bare Soils

Wabash silty clay loam and Ashland fine sandy loam were the only two soils used in this portion of the experiment. Their respective bulk densities were approximately 1.3 and 1.4 grams/cc. Each soil was treated with 0.05, 0.10, and 0.50 percent Arquad 2HT by weight. In addition, controls were maintained on each soil. All treatments were run in duplicate.

The treated soils were placed in threaded and waxed cardboard tubes which were 3 5/8 inches in height and 2 1/4 inches in diameter. Bulk densities were adjusted by tapping the sides of the tubes with a spatula. Next, a filter paper was placed on the surface to prevent the soil from being disturbed or removed by the added water.

For the purpose of holding and directing the infiltrating distilled water, a sheet metal tube was screwed to the top of the cardboard tube. A 3/8-inch hole was drilled through one side of the sheet metal tube so that its bottom edge was 1 1/8 inches above the soil surface. To the outside of the sheet metal tube, around the 3/8-inch hole, was attached a 5 1/2 inch "V" trough.

To determine the infiltration rate the coupled soil filled cardboard and sheet metal tubes were placed on a direct reading "Mettler" balance; this balance being capable of weighing to 0.01 gram. From a spout distilled water was directed into the top of the sheet metal tube. After the water level

raised to the bottom of the 3/8-inch hole, all additional water which did not infiltrate into the soil flowed out through the hole and was carried away by the trough. Approximately 20 seconds were required for the water to reach its constant level.

The weight of the filled tubes was recorded prior to the addition of the water and every 30 seconds for the duration of the test. Once the water had reached its constant level, any increase in weight was due only to infiltration. The time limit for the test was arbitrarily set for 20 minutes.

At the expiration of the test the head of water was poured off and the filled tubes reweighed. Thus the total amount of infiltrated water was equal to the difference between the initial weight and the final weight. The rate of infiltration was calculated on the basis of the weights recorded every 30 seconds.

RESULTS AND DISCUSSION

Effect of Arquad 2HT on Evaporation from a Bare Soil

Effect of Concentration of Arquad 2HT on Evaporation from a Bare Soil. As shown by Figs. 1-4[1], the minimum amount of Arquad 2HT necessary to cause a decrease in the rate of evaporation varied among the different soils. With Ladysmith silty clay loam a treatment of 0.014 percent resulted in 19 percent reduction in evaporation; the same amount on a kaolinite subsoil had no significant effect. However, with the kaolinite subsoil a 35 percent reduction in

[1]Data points for Figs. 1-9 are not available due to the loss of the original data in the fire at East Waters Hall, Kansas State College, on August 25, 1957. The present graphs were copied from a summary which had been recorded in the 1956 Annual Research Report of the Western Soil and Water Management Research Branch, Agricultural Research Service.

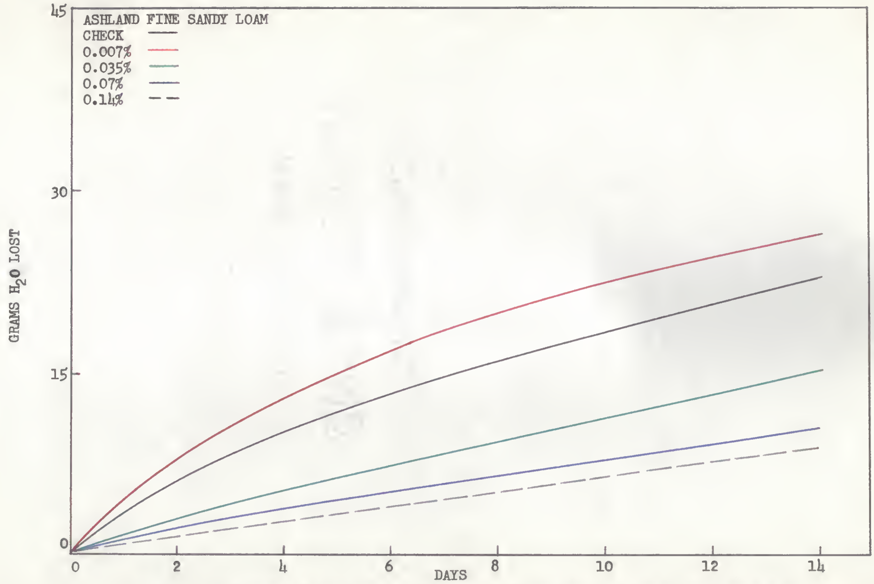

Fig. 1. Influence of concentration of Arquad 2HT on evaporation of soil moisture.

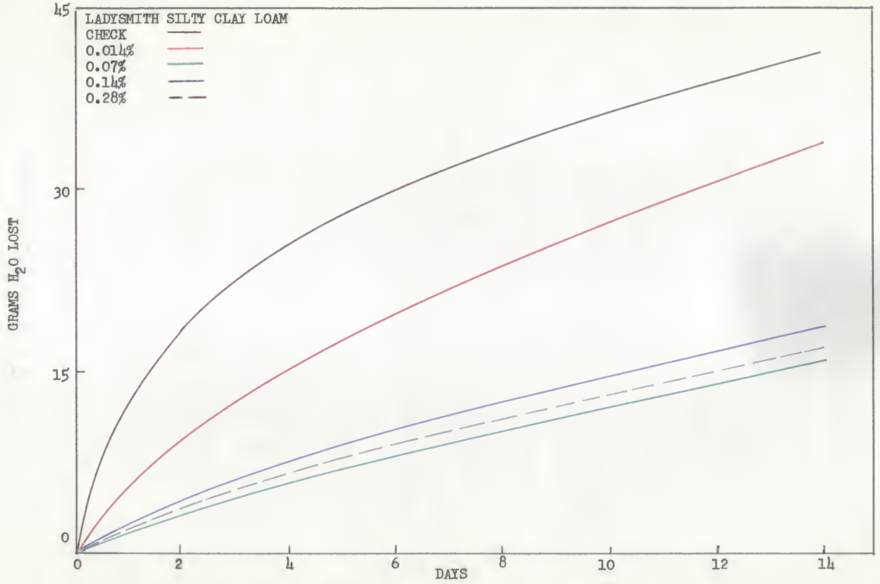

Fig. 2. Influence of concentration of Arquad 2HT on evaporation.

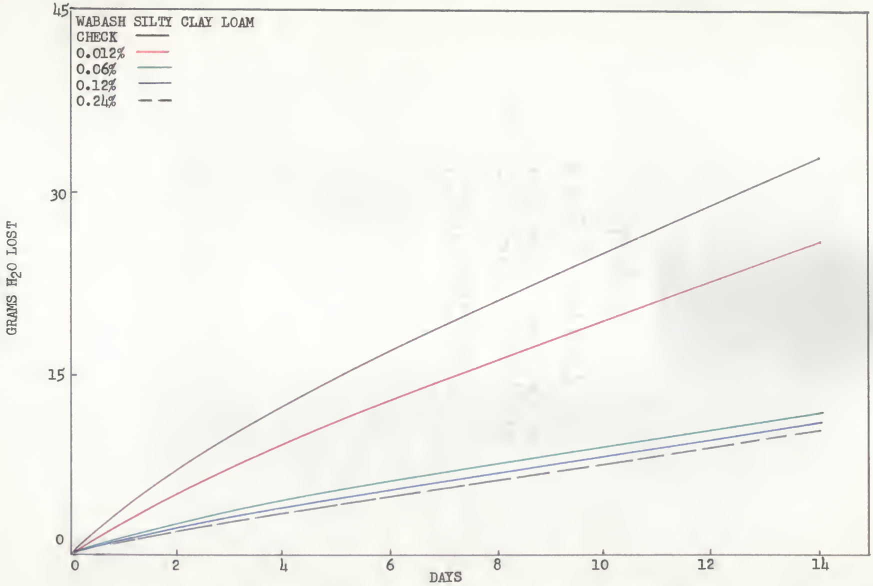

Fig. 3. Influence of concentration of Arquad 2HT on evaporation.

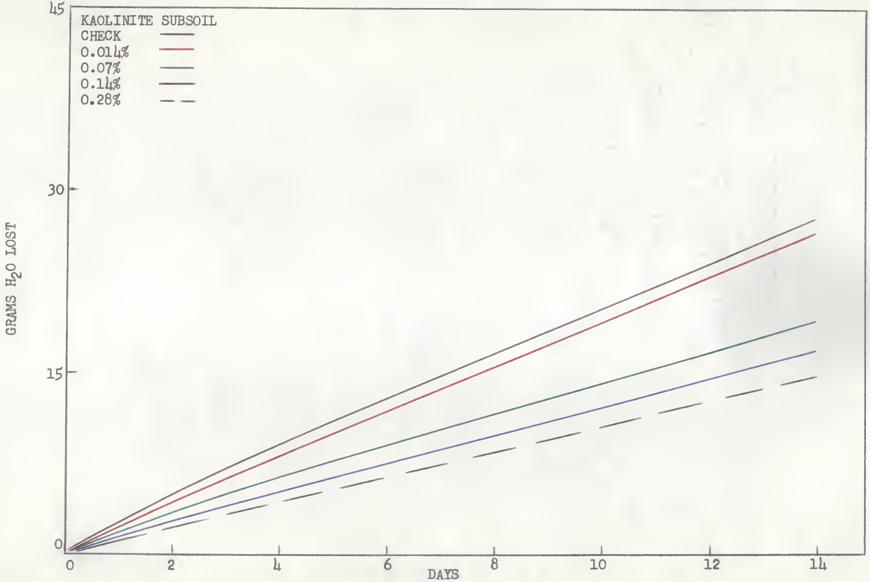

Fig. 4. Influence of concentration of Arquad 2HT on evaporation.

evaporation was achieved by the application of 0.07 percent Arquad 2HT. With the Wabash silty clay loam a minimum treatment of 0.012 percent resulted in a 19 percent reduction. On the Ashland fine sandy loam the lowest concentration of Arquad 2HT applied, .007 percent, caused an increase in evaporation (Fig. 1); however, with a greater concentration of 0.035 percent, evaporation decreased 30 percent. In general the graphs demonstrate that Arquad 2HT, even when applied in small concentration, will substantially reduce evaporation from soils.

From the graphs it is apparent that by increasing the concentration of Arquad 2HT within certain limits, a further reduction in evaporation may be acquired. With particular soils there appears to be a certain minimum concentration necessary for maximum retardation of evaporation. On the Ladysmith silty clay loam a maximum reduction of 63 percent was achieved with a concentration of 0.07 percent; the application of higher concentrations caused no significant differences. On the Wabash silty clay loam an 0.06 percent Arquad 2HT application decreased evaporation by 67 percent. As with the Ladysmith soil, further increases showed no significant effect on evaporation.

While the idea of achieving a maximum of evaporation reduction with a certain minimum amount of Arquad 2HT was not specifically borne out with the Ashland fine sandy loam and the kaolinite subsoil, nevertheless with both soils there was only a slight additional decrease in evaporation with Arquad 2HT concentrations greater than 0.07 percent.

<u>Effect of Depth of Arquad 2HT Treatment on Evaporation from a Bare Soil</u>. With but one exception, evaporation from all four soils varied inversely but not proportionately to the depth of Arquad 2HT treatment (Figs. 5-8). Per unit of treated soil, the first inch was by far the most effective in reduction of evaporation.

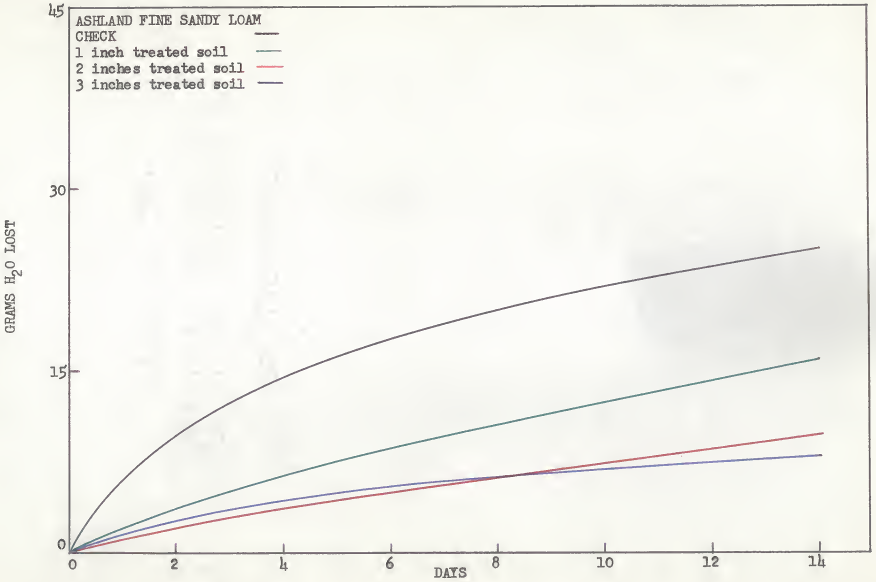

Fig. 5. Influence of depth of treated soil on evaporation.

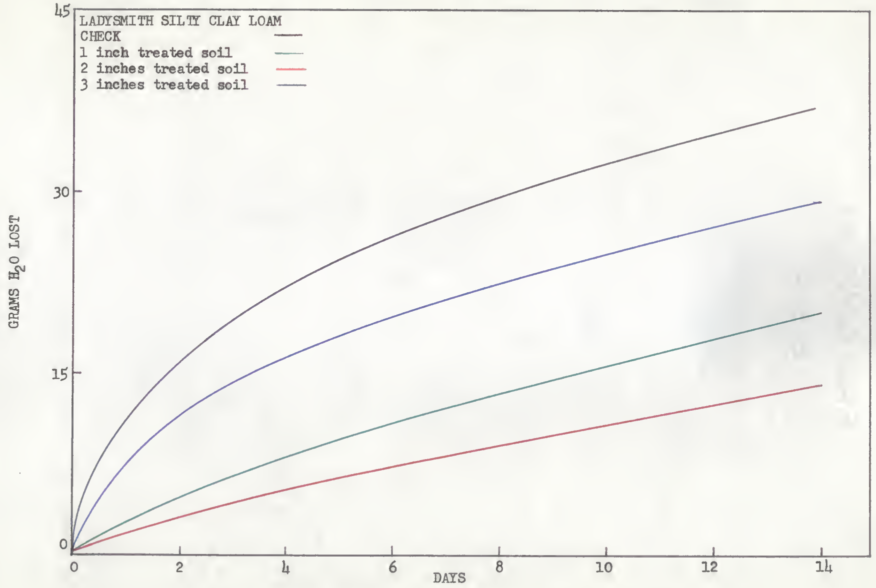

Fig. 6. Influence of depth of treated soil on evaporation.

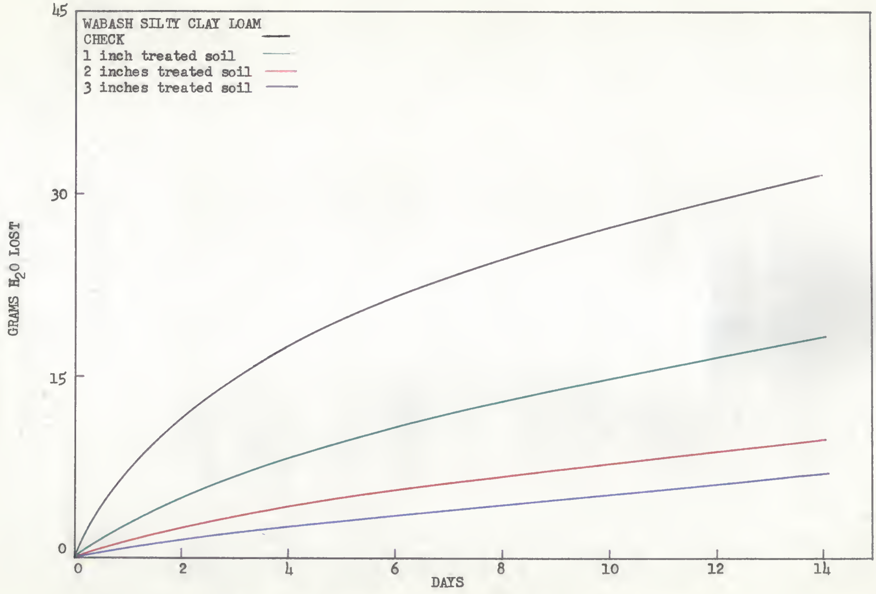

Fig. 7. Influence of depth of treated soil on evaporation.

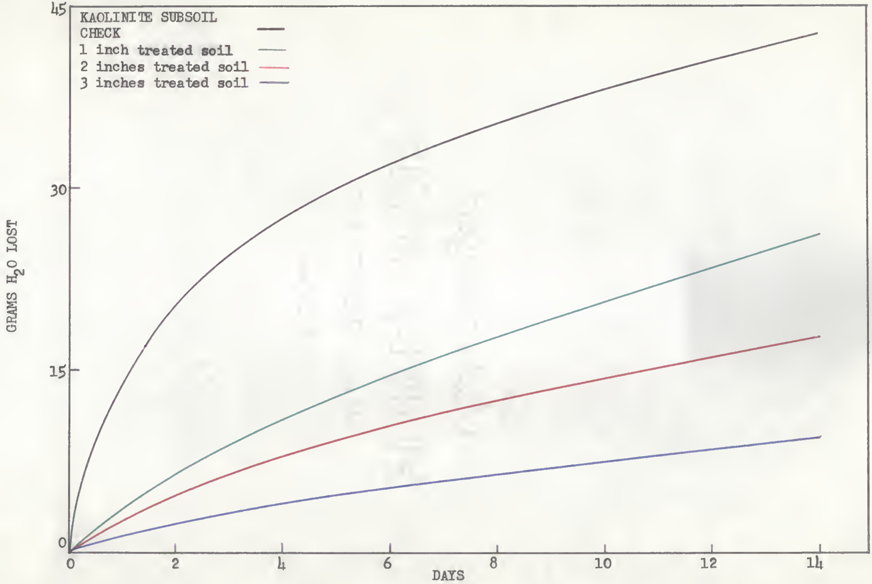

Fig. 8. Influence of depth of treated soil on evaporation.

The one exception occurred when the 3-inch depth of treatment on the Ladysmith silty clay loam lost more moisture by evaporation than did the 1- and 2-inch treatments (Fig. 6). In moistening this particular treatment in the inverse position, a continuous water pathway was established between the side of the tube and the treated soil. Throughout the 14 days of the experiment this water pathway apparently remained intact, allowing capillary water to continuously move to the soil surface and evaporate.

The graphs (Figs. 5-8) demonstrate that Arquad 2HT was very effective on Ashland fine sandy loam, Wabash silty clay loam, Ladysmith silty clay loam, and kaolinite subsoil; maximum evaporation reductions being 68, 75, 62, and 77 percent, respectively. With all but the Ladysmith soil the maximum reductions were realized with the three inch treatment.

Results from a preliminary experiment indicate a reverse trend in the effect of Arquad 2HT on Ashland fine sandy loam. In this particular experiment the soil was placed in a polyethylene tube 18 inches high and four inches in diameter. The depth of treatment was five inches and the concentration of the applied Arquad 2HT was 0.09 percent on a soil weight basis. The results showed no significant difference in evaporation rate between the check and the treated soil (Fig. 9).

This conflict may possibly be explained by differences in the experimental procedure. In the preliminary experiment the water was added to the top of the Ashland treated soil; this resulted in the establishment of continuous water films to the soil surface.

However when added to the top of the Wabash silty clay loam (Fig. 9), the water would not infiltrate into the soil and as a consequence had to be added to the bottom of the tube. The results correspond to those shown in Fig. 7.

Indications are that once capillary water columns have been established through an Arquad 2HT treated soil, they will remain active and nullify or partially nullify the effect of the treatment.

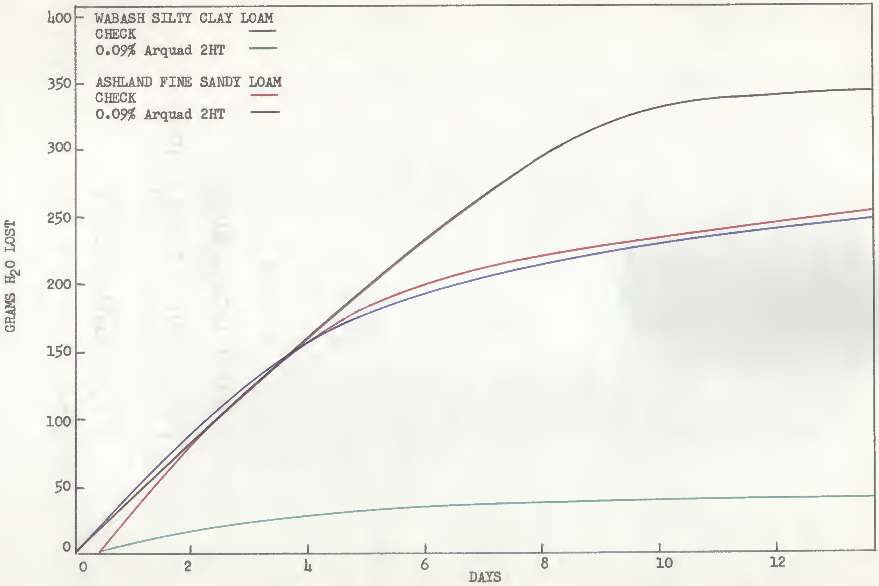

Fig. 9. Influence of 5-inch depth of Arquad 2HT treatment on evaporation.

Effect of Arquad 2HT on Moisture Retention

Only small to insignificant reductions in the moisture equivalent percentages were achieved by the treatment of the various soils with Arquad 2HT (Table 3). The magnitude of these results seem to be at variance with that of Grossi and Woolsey (6). In their experiment the treatment of a Putman silt loam with 0.1 percent Arquad 2HT caused a decrease in the moisture equivalent percentage from 25.09 percent to 9.62 percent. The reason for such discrepancies is not apparent at present.

Because of the difference in soil textures and amounts of Arquad 2HT applied, no specific comparison can be made between the soils listed in Table 3. However, indications are that in general the sandier soils show less change in moisture retention due to Arquad 2HT treatment than do soils with higher clay content.

Decrease in the moisture equivalent percentage is probably due to the inability of treated soils to absorb as much water during the soaking periods as was absorbed by untreated soils.

Table 3. Effect of Arquad 2HT on the moisture equivalent percentage.

Soil type	Arquad 2HT applied %*	Moisture equivalent** %
Summitt clay	None	29.44
Summitt clay	0.17	23.57
Munjor silty clay loam	None	28.70
Munjor silty clay loam	0.18	22.97
Garden City fine sandy loam	None	11.78
Garden City fine sandy loam	0.07	11.03
Albion fine sandy loam	None	16.80
Albion fine sandy loam	0.10	14.30
Keith silt loam	None	23.55
Keith silt loam	0.13	22.74
Ladysmith silty clay loam	None	28.12
Ladysmith silty clay loam	0.14	22.20

*Percent by soil weight.
**Average of duplicate sample.

Effect of Arquad 2HT on the Exchange Capacity of Certain Clay Minerals

From the figures shown in Table 4 it is apparent that the amount and rate of exchange of Arquad 2HT with calcium saturated clays was not very extensive. After washing the Wyoming bentonite four times with an excess of 1 percent Arquad 2HT dispersion, only 32.5 milliequivalents Arquad 2HT/100 grams had reacted with the clay. With the Fithian illite only 14.6 milliequivalents Arquad 2HT/100 grams were adsorbed. In both cases the extent of replacement was much less than might have been expected by more mobile ions such as NH_4^+. This lack of replacing power by the Arquad 2HT cation can probably be correlated with its large radius and small ionic charge.

Determination of the Mechanism of Reaction Between Arquad 2HT and Certain Clay Minerals

The treatment of calcium saturated Wyoming bentonite with an excess of 1 percent Arquad 2HT dispersion caused an 0.84A° expansion of the plates (Table 5). With Fithian illite and Drybranch kaolinite, no significant expansion occurred. As might be expected, the lack of expansion in the kaolinite and illite clays indicates that the sites of reaction with Arquad 2HT are only along the edges and terminal plates. This is further borne out by the small extent of their exchange reaction with Arquad 2HT.

When the calcium saturated Wyoming bentonite was oven dried at 130° C. the treated sample had a "d" spacing 3.60A° greater than that of the untreated clays. This difference can be attributed to the presence of Arquad 2HT cations between the clay plates; thus, the sites of reactivity with Arquad 2HT and Wyoming bentonite must be not only along the edges but between the crystal plates as well. This contention is partially substantiated by Arquad's

Table 4. Exchange reaction of Arquad 2HT with calcium saturated clay minerals.

Clays	Treatment	*Exchange capacity meq. Ca++/100 grams	Extent of exchange meq. Arquad 2HT/100 grams
Ca++ Wyoming bentonite	None	89.5	32.5
Ca++ Wyoming bentonite	1% Arquad 2HT	57.0	
Ca++ Fithian illite	None	21.0	14.6
Ca++ Fithian illite	1% Arquad 2HT	6.4	
Ca++ Drybranch Georgia kaolinite	None	3.8	3.8
Ca++ Drybranch Georgia kaolinite	1% Arquad 2HT	0	

*Average of 2 replications.

Table 5. Effect of Arquad 2HT on "d" spacing of certain clay minerals.

Clays	Treatment	"d" spacing		
		Oven dry 50° C.	Oven dry 130° C.	Expanded in H_2O saturated atms.
Ca++ Wyoming bentonite	None	12.95A°	10.26A°	16.43A°
Ca++ Wyoming bentonite	1% Arquad 2HT	13.79A°	13.86A°	16.18A°
Ca++ Fithian illite	None	10.14A°		
Ca++ Fithian illite	1% Arquad 2HT	10.06A°		
Ca++ Drybranch Georgia kaolinite	None	7.14A°		
Ca++ Drybranch Georgia kaolinite	1% Arquad 2HT	7.17A°		

greater extent of exchange with bentonite than with kaolinite and illite.

Expansion of the collapsed plates of both treated and untreated Wyoming bentonite was accomplished by placing the samples in a desiccator for four days with a water saturated atmosphere. There was no significant difference in "d" spacings of the expanded clays. Evidently Arquad 2HT has no retarding effect on the imbibition of water vapor by clays.

Effect of Arquad 2HT on the Germination of Wheat Seed

No significant difference in germination was evidenced on any one soil as the result of treatment with Arquad 2HT (Table 6). Increase in concentration had no effect. The percent of germination on the kaolinite subsoil was greatly below that of the other soils. However, this might be attributed to a severe decrease in soil aeration due to puddling the soil. This puddling was the result of mixing the soil at too high a moisture content.

Table 6. Effect of Arquad 2HT on germination.

*Concentration Arquad 2HT %	Percent germination**			
	Ashland fine sandy loam	Wabash silty clay loam	Kaolinite subsoil	Ladysmith silty clay loam
Check	97.0	92.0	5.0	97.5
.009	98.0	----	---	----
.016	----	91.0	---	----
.019	----	----	4.5	96.0
.047	92.5	----	---	----
.080	----	93.0	---	----
.093	93.5	----	5.0	91.5
.160	----	90.5	---	----
.190	95.5	----	5.0	92.5
.320	----	92.5	---	----
.370	----	----	6.0	91.0

*Percent by soil weight.
**Average of two replications.

Effect of Arquad 2HT on the Infiltration Rate into Bare Soils

Application of 0.50 percent Arquad 2HT to Ashland fine sandy loam effectively reduced both the amount and rate of infiltration (Fig. 10, Table 7). With this concentration the total reduction in the amount of infiltration was 95.6 percent. However, when smaller concentration of 0.05 and 0.10 percent were applied, infiltration was slightly increased. The reasons for such an increase are not known.

Table 7. Effect of Arquad 2HT on the amount of infiltration into a bare soil.

Soil	% Arquad 2HT	Ml H_2O infiltrated	% change infiltration
Wabash silty clay loam	check	84.6	-----
Wabash silty clay loam	0.05	22.3	-73.6
Wabash silty clay loam	0.10	13.4	-84.2
Wabash silty clay loam	0.50	2.9	-95.6
Ashland sandy loam	check	94.3	-----
Ashland sandy loam	0.05	96.1	+ 2.0
Ashland sandy loam	0.10	102.7	+ 9.0
Ashland sandy loam	0.50	3.0	-95.8

With Wabash silty clay loam all treatments substantially reduced infiltration (Fig. 11, Table 7). Reduction of 73.6, 84.2, and 95.6 percent was realized with applications of 0.05, 0.10, and 0.50 percent Arquad 2HT, respectively. It is of interest to note that the 0.50 percent Arquad 2HT application was just as effective in reducing infiltration on the sandier Ashland soil as it was on the Wabash silty clay loam. The over-all results point to the possibility of its utilization in canal and pond linings.

The practical use of Arquad 2HT in the retardation of soil moisture evaporation is complicated by its property of inhibiting infiltration. To be used successfully in the field will require additional research in means of application. Despite this disadvantage it seems apparent that Arquad 2HT may prove to be a convenient laboratory tool for evaporation research.

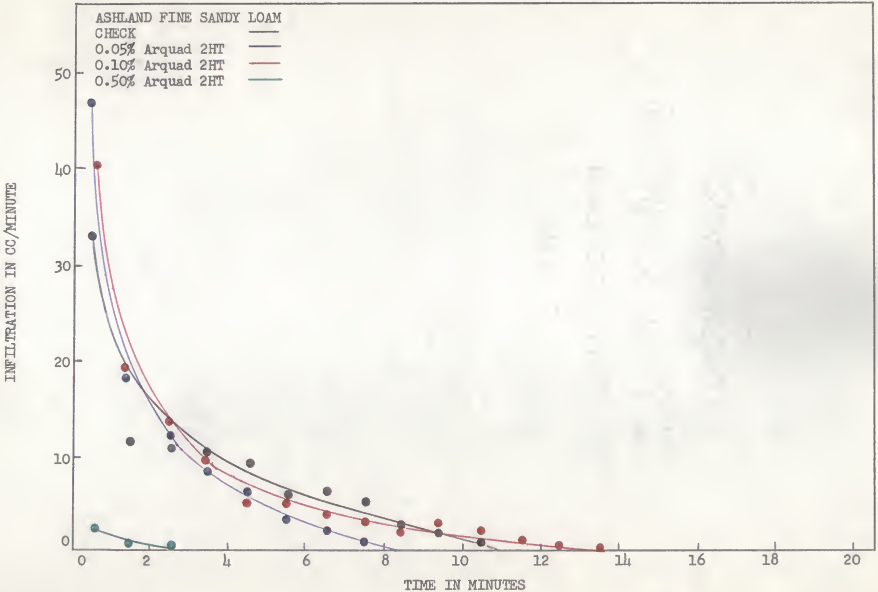

Fig. 10. Influence of Arquad 2HT on infiltration rate.

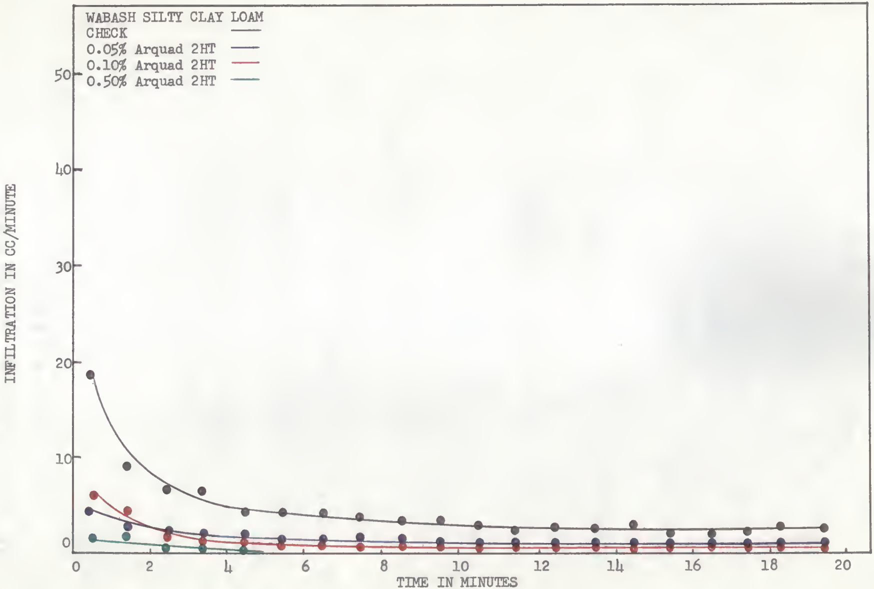

Fig. 11. Influence of Arquad 2HT on infiltration rate.

SUMMARY

Arquad 2HT effectively reduces evaporation from soils by inhibiting capillary flow to the soil surface. Concentration as low as 0.012, 0.014, 0.035, and 0.07 percent significantly reduced evaporation from Wabash silty clay loam, Ladysmith silty clay loam, Ashland fine sandy loam, and kaolinite subsoil, respectively.

Apparently on some soils maximum reduction of evaporation can be secured by the application of a certain minimum concentration of Arquad 2HT. Concentration greater than 0.07 percent on Ladysmith silty clay loam and 0.06 percent on Wabash silty clay loam caused no significant additional reduction. With Ashland fine sandy loam and kaolinite subsoil, concentration greater than 0.07 percent only slightly decreased evaporation.

The rate of evaporation from all soils was inversely but not proportionately related to depth of Arquad 2HT treatment. The top inch of treated soil was the most effective in evaporation reduction.

Once capillary water columns have been established through Arquad 2HT treated soils, they remain active and partially nullify the effect of the treatment.

With the concentration used, 0.07 to 0.18 percent, Arquad 2HT caused small decreases in the moisture equivalent percentages.

Arquad 2HT is capable of entering into cation exchange with the clay minerals; however, the extent of reaction is small in comparison to the more mobile inorganic cation. Presumably this small exchange is partially the result of the large size and small charge of the Arquad 2HT cation.

Since no change in "d" spacing was evidenced when Fithian illite and Drybranch Georgia kaolinite were treated with Arquad 2HT, the sites of reaction

must be along the edges of the clay plates. However, the sites of reaction with Wyoming bentonite are both along the edges and between the plates. This is indicated by the collapsed treated bentonite having a "d" spacing 3.60A° greater than the untreated collapsed bentonite.

The presence of Arquad 2HT on Wyoming bentonite did not noticeably retard the imbibition of water vapor.

No significant differences were evidenced by the germination of Pawnee wheat seed in Arquad 2HT treated soils. Variation in concentration had no noticeable effect.

Arquad 2HT in concentrations of 0.50 percent reduced infiltration 95.8 percent on Ashland fine sandy loam. Treatments of 0.05 and 0.10 percent slightly increased infiltration.

When applied to a Wabash silty clay loam, all concentrations used substantially reduced infiltration. Treatments of 0.05, 0.10, and 0.50 percent decreased infiltration 73.6, 84.2, and 95.6 percent, respectively.

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THE INFLUENCE OF A WATERPROOFING AGENT
ON SOIL MOISTURE PROPERTIES

by

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Recent drought conditions have demonstrated the effects of insufficient soil moisture on agriculture. One of the primary factors contributing to such a moisture deficiency is that of evaporation.

The attempted reduction of evaporation from soils has been the subject of numerous studies. Most such experiments have centered around the employment of various types of mulches. In general the results have been contradictory.

Research initiated with Arquad 2HT, a quaternary ammonium salt, has shown that this compound possesses the ability to disrupt capillary conductivity in soils. It was the main purpose of this experiment to evaluate the possibility of utilizing this characteristic of capillary disruption for the reduction of soil moisture losses due to evaporation.

To determine the effect of Arquad 2HT on evaporation from a bare soil, the top two inches of soil columns from four different soils were treated with 0.1, 0.5, 1.0, and 2.0 percent Arquad 2HT dispersions. After drying the treated soil, columns were wet to the 1/3 atmosphere percentage. While drying, the columns were weighed periodically to determine moisture loss. Effectiveness of treatment was based on the amount of water lost.

The procedure used to find the effect of depth of treatment on evaporation was the same as mentioned above except that the soils were treated with 10 percent dispersion at one, two, and three inch depths.

The influence of Arquad 2HT on soil moisture retention was measured by the difference in the moisture equivalent percentage of treated and untreated soils.

The extent of Arquad 2HT exchange with calcium saturated bentonite, illite, and kaolinite clays was determined by the difference in milliequivalents Ca^{++}/100 grams replaced from Arquad treated and untreated clay samples. Replacement of calcium was accomplished by the use of ammonium acetate.

To help find the mechanism of reaction between these clay minerals and Arquad 2HT, X-ray diffraction was used to determine "d" spacings on treated and untreated samples which had been dried, collapsed, and expanded.

To judge the influence of Arquad 2HT on germination, wheat seeds were planted in pans of each of the four soils. The soils had been moistened with Arquad dispersions to the 1/3 atmosphere percentage. Concentration varied from .009 to .373 percent. The effect of the treatment was based on the number of seeds germinated.

In determining infiltration rates, soil filled tubes were subjected to a constant water head and weighed periodically. Soils were treated with 0.05, 0.10, and 0.50 percent Arquad 2HT. Rate of infiltration was calculated on the basis of increase in weight with time.

Results from the experiment showed that Arquad 2HT is very effective in reducing evaporation even when applied in small concentration.

Rates of evaporation were inverse but not proportional to depth of treatment. The first inch of treatment was the most effective in reducing evaporation.

Establishment of water columns through treated soils partially nullify the effects of the treatment.

With the concentrations of Arquad 2HT used, only small to insignificant reductions in the moisture equivalent percentages were achieved.

The extent of exchange between Arquad 2HT and illite and bentonite clays was small. This presumably was the result of the large ionic size and small charge of the Arquad 2HT cation.

The sites of reaction between Arquad 2HT and bentonite clay were between the plates and along the plate edges.

Arquad 2HT treatment does not prevent the imbibition of water vapor by clays.

Regardless of concentration used, Arquad 2HT caused no significant difference in wheat seed germination.

On Wabash silty clay loam all Arquad 2HT treatment substantially reduced infiltration. With Ashland fine sandy loam only the 0.50 percent treatment decreased infiltration; smaller applications slightly increased infiltration.